Welder Guide Book

ALL-POSITIONAL RUTILE FLUX CORED WIRES
FOR NON AND LOW ALLOYED STEELS

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Product	AWS A5.20	
OK Tubrod 15.13	E71T-1C H4	E71T-1M H8
OK Tubrod 15.13S	E71T-9 H4	
OK Tubrod 15.14	E71T-1C	E71T-1M
FILARC PZ6113	E71T-1C H4	E71T-1M H8
FILARC PZ6114		E71T-1MJ H4
FILARC PZ6114S	E71T-1CJ H4	
	AWS A5.29	
OK Tubrod 15.17		E81T1-Ni1M
FILARC PZ6115		
FILARC PZ6116S	E81T1-K2 J H4	
FILARC PZ6138		E81T1-Ni1M JH4
FILARC PZ6138 SR		E81T1-Ni1M J
FILARC PZ6138S SR	E81T1-Ni1C J	
	AWS A5.29	
Dual Shield 55		E91T1-Ni1M
Dual Shield 62		E101T1-G
Dual Shield II 81-K2		E81T1-K2
OK Tubrod 15.09		E111T1-K3MJ-H4

Introduction

This guide provides practical information on the use of the ESAB all-positional rutile cored wires listed below. When correctly applied, these wires provide:

- Excellent weldability with spray arc droplet transfer in all welding positions.
- Good weld appearance with smooth weld metal wetting.
- High productivity, especially in vertical-up position.
- Defect free welds with good mechanical properties.
- Low-hydrogen weld metal.

EN ISO 17632-A		Shielding Gas	
T 42 2 P C 1 H5	T 46 2 P M 1 H10	CO_2	Ar / 15-25 CO_2
T 46 3 P C 2 H5		CO_2	
T 46 2 P C 2 H5	T 46 2 P M 2 H5	CO_2	Ar / 15-25 CO_2
T 42 2 P C 1 H5	T 46 2 P M 1 H10	CO_2	Ar / 15-25 CO_2
	T 46 4 P M 1 H5		Ar / 15-25 CO_2
T 46 4 P C 1 H5		CO_2	
EN ISO 17632-A			
T 46 3 1Ni P C 2 H5	T 46 4 1Ni P M 2 H5	CO_2	Ar / 15-25 CO_2
T 50 5 2Ni P M 2 H5			Ar / 15-25% CO_2
T 46 6 1.5Ni P C 1 H5		CO_2	
	T 50 6 1Ni P M 1 H5		Ar / 15-25 CO_2
	T 46 6 1Ni P M 1 H5		Ar / 15-25 CO_2
T 46 6 1Ni P C 1 H5		CO_2	
EN ISO 18276-A			
	T 55 4 Z P M 2 H5		Ar / 15-25 CO_2
	T 62 4 Mn1.5Ni P M 2 H5		Ar / 15-25 CO_2
			Ar / 15-25 CO_2
	T 69 4 2NiMo P M 2 H5		Ar / 15-25 CO_2

Before you start welding

In order to fully benefit from the excellent weldability of ESAB all-positional rutile cored wires, the welding equipment needs to be maintained in good condition. The following checklist serves as a guide.

CHECKLIST

Contact tips and gas nozzle

- Remove spatter and replace worn or damaged contact tip.
- Grind the end of the liner conical for optimal fitting of the contact tip (ESAB M8).

correct incorrect

Contact tip size, liner size and wire diameter

- Ensure that the contact tip is the correct size and fits tightly.
- Ensure the gas nozzle is free from spatter.
- *When using M21 shielding gas;* ensure that the contact tip size is dimensioned one size up. (I.e. for Ø1,2mm wire use contact tip intended for Ø1,4mm wire. Hole should be Ø1,7mm).

Liner

- Spiral steel liners are recommended.
- Ensure that the liner has the correct inner diameter for the wire size to be used.
- Check liners regularly for kinks and excessive wear and replace when needed.
- Clean liners regularly using compressed air. Firstly remove contact tip.

Gas and water

- Check gas and water connections for leaks.
- Check if water cooler is filled and pump operates satisfactorily.

Wire feed unit

- Position wire guide tubes as close as possible to the rollers to prevent kinking of the wire. A substantial amount of fine metallic shavings underneath the drive rolls indicates misalignment.

Correct

Incorrect

Before you start welding

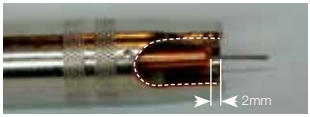
- Use drive rolls with a V-groove and flat pressure rolls.
- Use knurled rolls only when friction in the liner causes smooth rolls to slip e.g. with long, extremely curved cable assemblies. Knurled rolls give increased liner and contact tip wear.
- Check that the groove size is correct for the wire diameter.
- Apply the correct pressure on feed rolls. Too much pressure flattens the wire, resulting in feedings problems and higher liner and contact tip wear. Insufficient pressure may cause wire to slip in the feed rolls, resulting in irregular feeding and possible wire burnback.
- Check that the wire is feeding correctly from the contact tip.

Smooth Knurled

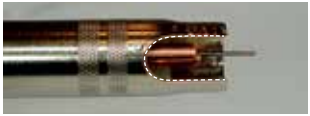
Shielding gas

- Check that the appropriate gas is used (page 3). Adjust gas flow rate between 15 and 20 l/min.
- Use 20 l/min. when welding outside.
- Check that the gas flow from the gas nozzle is at the recommended rate.
- Check the gas flow rate again if the gas nozzle diameter is changed.

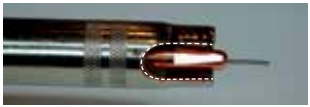
Contact tip and gas nozzle



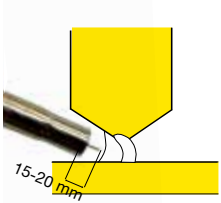
Correct positioning of contact tip.



Incorrect. Contact tip too recessed.



Incorrect. Contact tip protruding beyond gas nozzle.



Ideal stick-out for wire diameters 1.2 and 1.4mm
(20-25mm for Ø 1.6mm).

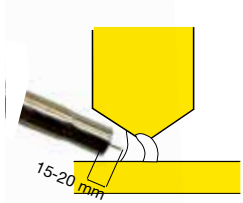
It is essential to fit the gas nozzle and contact tip at the right distance relative to each other. The ideal distance of the contact tip is 2mm recessed. A longer distance will force the welder to use too long a stick-out, resulting in poor weldability. This may lead to lack of fusion and slag traps, particularly in narrow joints. Contact tips protruding beyond the gas nozzle can result in insufficient gas shielding.

Correct stick-out length
The stick-out is the distance between the contact tip and workpiece and must be kept between 15 and 20mm (Ø1.2 and 1.4mm). Excessive stick-out results in a too short arc length, larger droplets, an unstable arc and spatter, so poor weldability. Additionally, it may reduce the gas protection which can lead to porosity.

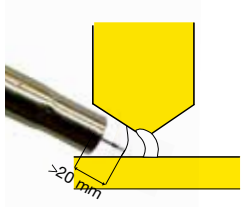
If the stick-out is too short, the arc length becomes too long, the weld pool will get hotter and more difficult to control.

Gas nozzle diameter

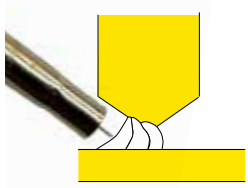
Various nozzle diameters must be available to allow satisfactory access to the joint, to maintain the above recommended stick-out, and to ensure proper shielding gas protection. Small diameter gas nozzles are used for the first layers only. Revert to the standard gas nozzle diameter when access to the weld joint allows this, so full gas protection can be assured.



Correct. Use a smaller diameter nozzle or a conical nozzle for the 1st layers in the root area.



Incorrect. Use of standard gas nozzle restricts access to narrow joints, resulting in too long a stick-out



Correct. Use of standard gas nozzle for completing the joint ensures good gas protection and correct stick-out.

Polarity and inductance

Always use positive polarity for ESAB all-positional rutile cored wires.

DC+ POSITIVE POLARITY

ESAB all-positional rutile cored wires operate in the spray arc mode at all welding currents, so no inductance is needed. Switch off the inductance or select minimum setting if the inductance can not be disconnected.

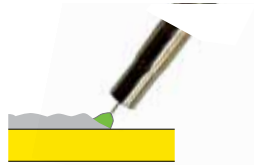
Correct. Minimum choke setting selected.

Welding parameter setting

A given welding current requires a specific arc voltage for optimum weldability. The welding current is set by adjusting the wire feed speed control. The arc voltage is regulated by the open circuit voltage (OCV) setting of the power source. Pages 16 + 17 give average parameters for various wire diameters and welding positions.

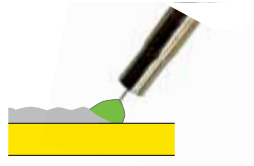
How to achieve the optimum setting?
For the following procedure, it is vitally important to keep the stick-out constant within the correct range for each welding position.

- From the range given in the table on pages 16 + 17, select a welding current (I) which suits your application.
- Start welding with the lowest voltage value from the given range. This may result in stubbing, however wire burnback will be avoided.



Correct. Correct arc length. Stable and concentrated arc with a quiet spray droplet transfer.

Incorrect. Arc length too short. Wire dips into weld pool (stubbing) caused by too low an arc voltage, too high a wire speed or too long a stick-out.



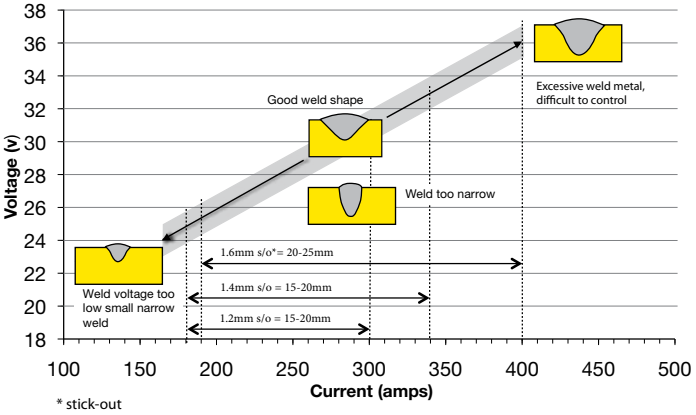
Incorrect. Arc length too long. Arc becomes too wide, giving insufficient penetration and a risk of slag traps. Also a risk of burnback to the contact tip. This may be caused by the arc voltage being too high, the wire feed speed too low or the stick-out being too short.

- Increase the arc voltage in steps of 1 or 2V, until the arc becomes stable, smooth and spatter free, with a slightly crackling sound. Ensure the correct stick-out length is maintained.

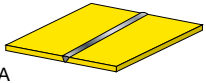
- If a different current is required, i.e change of welding position, the procedure described on the previous page needs to be repeated.

- The Table on pages 16 + 17 gives settings for Ar/20CO_2 mixed gas. The arc voltage needs to be increased by 1-2V when CO_2 shielding gas is being used. Note that the CO_2 arc is not as smooth, with a more globular droplet transfer and more spatter.

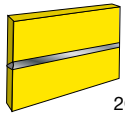
NOTE: As mentioned, stick-out control is very important. If the recommended stick-out length is not maintained constant, weldability will fluctuate. Shortening the stick-out will result in an increasing current and a longer arc. Lengthening the stick-out will result in a lower current and the arc being too short.



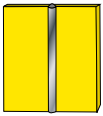
ASME and EN ISO positions



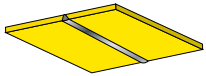
1G/PA



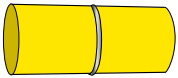
2G/PC



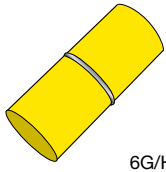
3G/PF&PG



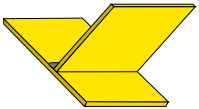
4G/PE



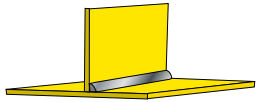
5G/PF&PG



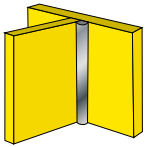
6G/HL045



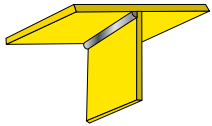
1F/PA



2F/PB



3F/PF&PG

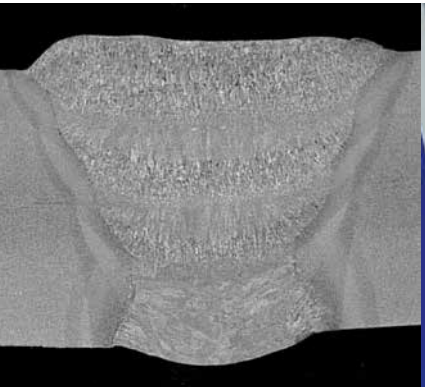


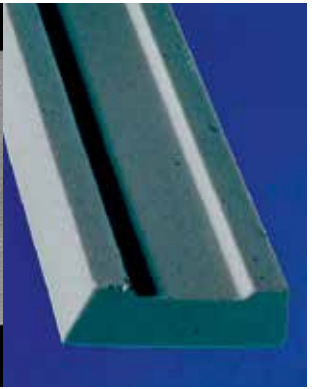
4F/PD

Choice of wire size

The diameter range of ESAB all-positional rutile cored wires is 1.2-1.6mm, allowing optimal productivity for various combinations of plate thicknesses and welding positions. Diameter 1.4mm provides a useful compromise between productivity and the use of a single diameter wire for all welding positions. The table on page 15 shows suitable recommendations for each diameter.
Vertical down welding is not recommended, particularly on thicker plate material (>5mm), because of the risk of cracking.

Single-sided root run welding
All-positional rutile cored wires are not suited for welding single-sided open root runs. In many applications, however, high quality single-sided root runs in V-joints can be produced very economically on ceramic backing materials. Always use ceramic backing with a rectangular groove.





PF/3G butt weld in 18mm plate.
Root run on ceramic backing.

	Position	Ø 1.2mm	Ø 1.4mm	Ø 1.6mm
		Suitability for a typical application		
–	1F/PA	yes[2]	yes	yes
–	2F/PB	yes[2]	yes	yes
–	3F↑/PF	yes	yes	yes
–	4F/PD	yes	yes	yes
Root	1G/PA	on backing[1]	on backing[1]	not recommended
Fill	1G/PA	yes[2]	yes	yes
Root	2G/PC	on backing	on backing	not recommended
Fill	2G/PC	yes	yes	yes
Root	3G/PF	on backing	on backing[3]	not recommended
Fill	3G/PF	yes	yes	possible[3]
Root	4G/PE	no	no	no
Fill	4G/PE	yes	yes[3]	not recommended
Root	5G/PF	no	no	no
Fill	5G/PF	yes	yes[3]	not recommended
Root	6G/PF	no	no	no
Fill	6G/PF	yes	yes	not recommended

1 One-sided root pass on ceramic backing, V-joint. Centerline cracking may occur at welding currents over 200A, see page 31.

2 1.4 and 1.6mm sizes will improve productivity.

3 1.2mm size is preferred.

Recommended parameter settings

Position		1.2mm (15-20mm stickout)		
		I (A)	v wire (m/min)	U (V)*
1F/2F		180-300	6.0-14.0	24-31
3F/4F		180-250	6.0-10.0	23-28
1G	Root**	180-200	6.0-8.0	23-26
	Fill	180-280	6.0-12.0	25-31
2G	Root**	180-210	6.0-8.5	23-26
	Fill	180-260	6.0-10.0	25-29
3G	Root**	180-220	6.0-8.5	23-27
	Fill	180-240	6.0-9.0	24-28
4G	Root	no		
	Fill	180-260	6.0-10.0	24-28
5G	Root	no		
	Fill	180-240	6.0-9.0	24-28
6G	Root	no		
	Fill	180-240	6.0-9.0	24-28

* Arc voltage valid for Ar/20%CO_2 mixed gas. Increase arc voltage 1-2V for CO_2.
** On ceramic backing.

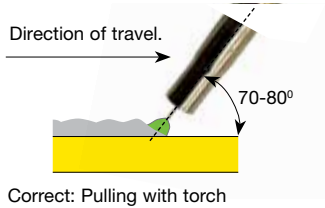
	1.4mm (15-20mm stickout)			1.6mm (20-25mm stickout)		
	I (A)	v wire (m/min)	U (V)*	I (A)	v wire (m/-min)	U (V)*
	190-340	4.5-10.5	24-32	200-400	4.0-10.5	25-35
	190-240	4.5-6.0	24-28	3F: 220-250 4F: 200-250	5.0-5.8 4.0-5.8	24-28 25-29
	not recommended			not recommended		
	190-340	4.4-10.5	24-32	210-400	4.5-10.5	25-35
	180-210 190-300	4.0-5.0 4.4-8.5	23-27 24-32	190-220 210-320	3.7-5.0 4.5-8.0	25-28 25-33
	180-210 190-240	4.0-5.5 4.4-6.2	23-27 24-29	not recommended 220-250	 5.0-6.0	 24-28
	not recommended 190-240	4.5-6.0	24-28	not recommended		
	not recommended 190-240	4.5-6.0	24-28	not recommended		
	not recommended 190-240	4.5-6.0	24-28	not recommended		

Direction of travel

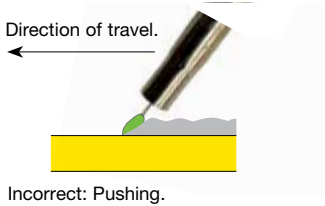
To ensure good penetration and to prevent slag running ahead of the weld pool:

Always weld pulling.

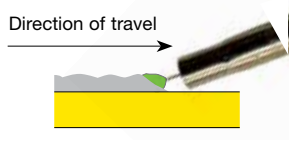
Pushing can deliver a reasonable weld appearance, but penetration is often poor. There is also a chance of slag running ahead of the weld pool, causing slag traps and lack of fusion. The same is valid for pulling when the torch angle is too small.



Correct: Pulling with torch angle at 70-80°.



Incorrect: Pushing.



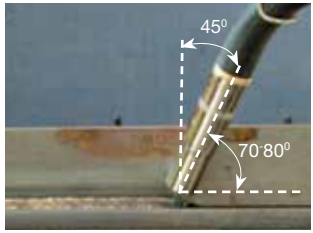
Incorrect: Pulling with the torch angle too small.

Welding positions

The following are typical situations where the correct torch position plays an important role in avoiding weld defects.

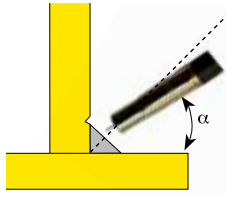
2F/PB - horizontal-vertical fillet

The photo shows the ideal torch position, using the recommended pulling technique. Still undercut and sagging faults can occur in this position, the possible causes of these faults are listed below.



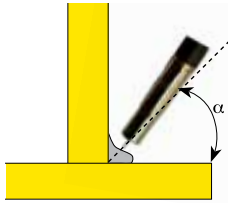
Undercut:

- Welding current too high.
- Arc voltage too high.
- Travel speed too fast.
- Arc positioned too close to the vertical plate.
- Torch angle (α) too small.



Sagging:

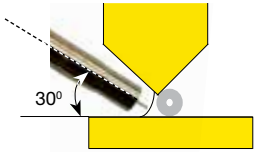
- Welding current too high.
- Arc voltage too high.
- Torch angle (α) too large.
- Layer too thick.
- Travel speed too slow.



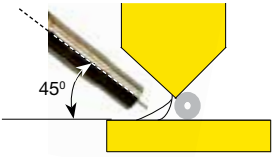
2G/PC - horizontal-vertical

The correct torch position will depend on plate thickness and joint angle. If the torch positions shown cannot be used, it is recommended that the joint angle or root gap is increased.

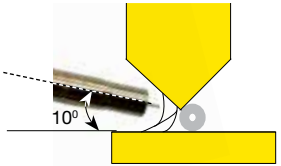
Always maintain the torch angle of 70-80° relative to the weld bead and direction of travel as advised on page 18. Maintain a steady travel speed to achieve a regular bead thickness, without sagging.



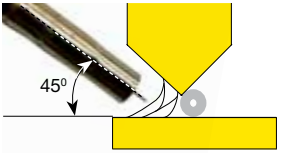
A. Root run welded on round ceramic. Avoid beads that are too thick.



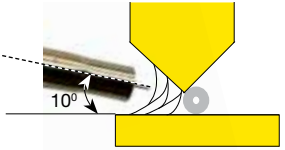
B. 2nd run positioned towards horizontal plate.



C. 3rd run completes 2nd layer.



D. 4th run creates a favourable platform for the following runs.

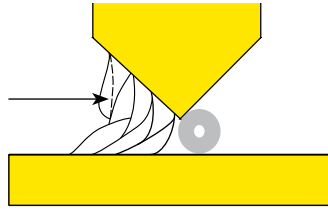


E. 5th run. Note how layers are always built-up from the bottom side as weld thickness increases.

Avoid sagging
Sagging (rollover) is typically caused by:

- Travel speed too slow.
- Incorrect torch angle.
- Welding current too high.
- Wrong weld bead sequence.

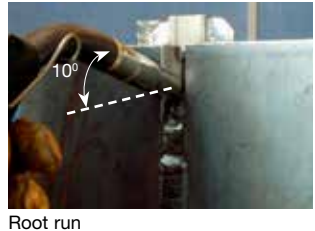
Sagging requires grinding to avoid defects when welding subsequent passes. Sagging can be avoided by keeping the weld beads as flat as possible.



Avoid sagging but if it occurs then grind back to dotted line as shown above.

3G↑/3F↑/PF - vertical up
ESAB all-positional cored wires can weld a 4mm throat fillet weld at welding speeds up to 18cm/min. without weaving.

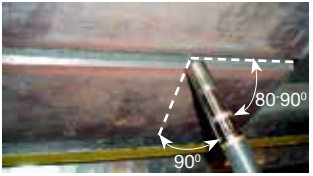
For butt welding in the vertical up position, root runs are deposited onto ceramic backing materials with a rectangular groove. The joint angle must allow good access to the root area. If access is restricted then use a narrower gaz nozzle.



Root run

Filling

4G/PE 4F/PD - overhead
Use a stick electrode for the root run and fill with ESAB all-positional rutile cored wires. Photo right gives the ideal torch positioning.



Vertical up welding techniques

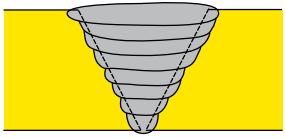
Full width weaving

Full width weaving is commonly practised with ESAB all-positional rutile cored wires. However, care must be taken to ensure that the heat input is not excessive, otherwise weld metal impact properties may deteriorate.

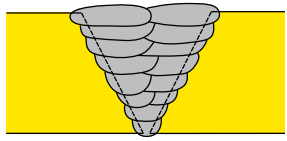
The weaving technique involves crossing the joint from edge to edge in a straight line, whilst gradually moving upwards in the direction of travel.

Split weave and stringer beads.

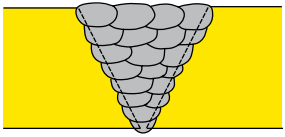
The split weave and stringer bead techniques should be used where optimal subzero weld metal toughness properties are required e.g. in offshore fabrication.



Full width weaving: high heat input



Split weave: medium heat input



Stringer beads: low heat input

	Heat input
Full width weaving:	2.5-3.5 kJ/mm
Split weave:	1.5-2.5 kJ/mm
Stringer bead:	1.0-1.5 kJ/mm

Mechanised welding

Mechanised welding is a great way to fully benefit from the productivity of ESAB all positional rutile cored wires. It allows higher welding currents and travel speeds which are not manageable in manual welding, whilst monotonous work is avoided. The ESAB range of light mechanisation equipment for MIG/MAG and FCAW consists of:

- ESAB Miggytrac for horizontal welds.
- ESAB Railtrac for horizontal and horizontal vertical welds.
- ESAB Pipeweld Orbiter for circumferential joints.

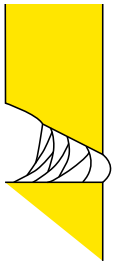
Miggytrac B501.

Railtrac B42V.

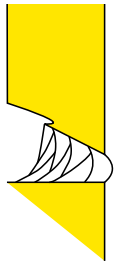
Pipeweld Orbiter.

Grinding

Grinding may be necessary to correct weld metal sagging or beads which are too convex. Remove only the most obvious irregularities and avoid making deep grooves. They can lead to slag traps and lack of fusion when welding subsequent runs.



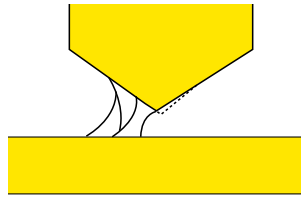
Correct.



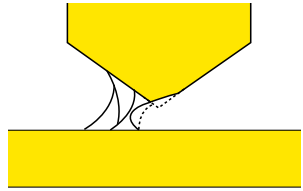
Incorrect.

Always grind stop-start areas.

Root run treatment
When welding double-sided joints, before welding the first run on the second side, ensure that grinding is used to remove the root run from the first side to sound metal.



Correct.



Incorrect.
Grinding wheel pushed into root, resulting in a deep groove. The narrow joint is almost inaccessible to the torch.

Trouble shooting

Process faults

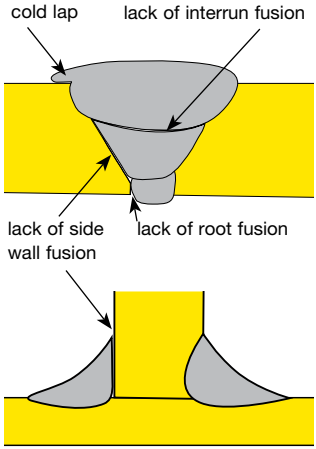
Although good equipment maintenance and good welder training will help prevent process faults, they can never be avoided completely. In such cases, understanding the most common causes will help the welder to solve any problems quickly. Listed below are the most common process faults and their likely causes.

Process faults	Likely causes
1. wire stubbing	- incorrect parameters
2. wire burn-back	- spool brake too tight - incorrect parameter settings - damaged/worn contact tip - incorrect machine burn back setting
3. excess spatter	- incorrect parameter settings - wrong shielding gas - incorrect gas flow - erratic wire feed - damaged or worn contact tip
4. erratic wire feed	- roll pressure too low, causing wire slippage - roll pressure too high, deforming the wire - worn drive rolls - misalignment of rolls or guide tubes - damaged or worn liner - incorrect liner type/diameter - incorrect contact tip size - damaged or worn contact tip - spool brake too tight - spool brake too loose (tangled wire)
5. unstable arc	- incorrect parameters - erratic wire feeding - incorrect gas flow - magnetic arc blow, due to poor earth connection

Trouble shooting

Weld defects

Lack of fusion defects.
There are several types of lack of fusion defects, but all share the same feature in that deposited weld metal has not fused with the parent metal or previously deposited weld metal. Typical forms of lack of fusion are shown in a V-butt weld. They can also occur in other types of butt joints. Also shown is a typical side wall defect in a fillet weld.

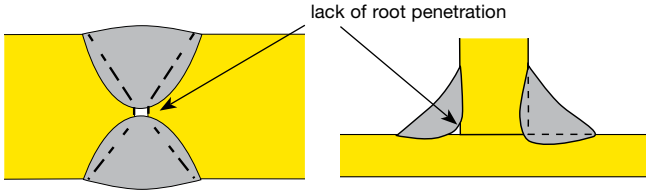


Lack of fusion defects

Possible causes	Remedies
General	
• travel speed too high	- reduce travel speed/allow more dwell time at edges
• wrong parameter setting	- adjust parameters
• pushing technique	- pulling technique, 70-80° torch angle.
Lack of root fusion*	- enlarge root gap
Fillet: lack of fusion at standing leg	
• Torch directed too much towards horizontal leg	- change torch orientation

**use of ceramic backing is recommended for single-sided root run welding, see page 14.*

Lack of penetration
This occurs when the weld metal fails to extend into the complete root area of a joint. Shown below are two typical cases.



Lack of penetration

Possible causes	Remedies
General	
• welding current too low	- increase wire feed speed and arc voltage
• arc voltage too high	- reduce arc voltage
• travel speed too high	- reduce travel speed
• travel speed too low	- Increase travel speed; speed; avoid slag running ahead of weld pool
• pushing technique	- use pulling technique
• torch angle too small	- use correct angle α relative to joint, see page 21; aim the arc at the leading edge of the pool
Butt welds - incorrect joint preparation	
• root gap too small	- increase gap - reduce face
• included joint angle too small	- increase angle

Trouble shooting

Porosity

Possible causes	Remedies
• draught/wind	- close doors or windows. Use shielding tents if outside
• paint, grease or dirt	- clean and dry plates in the weld area
• gas nozzle clogged	- clean/replace
• gas nozzle distorted	- replace
• gas nozzle too small	- use larger gas nozzle
• gas flow too high	- adjust flow rate
• gas leaks in system	- check by blocking gas cup; aspirate air continued gas flow indicates leaks
• water leaks in cooled guns	- check connections
• gas cup to workpiece	- check positioning of contact tip distance too long relative to gas cup; readjust parameters

Slag inclusions

Slag inclusions occur when molten slag is allowed to run ahead of the welding arc and gets trapped below the solidifying weld pool.
All-positional rutile cored wires are prone to this, because of their fast freezing slag and their easy weldability.

The most likely welding positions for slag inclusions to occur are the 1G/PA and 2G/PC positions, particularly in joint preparations with a small included angle.

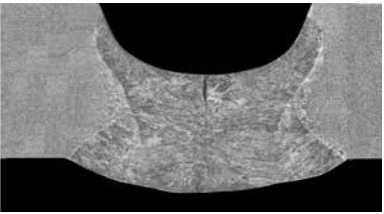
Most important is to control the penetration.
To obtain sufficient penetration, welders must use the correct stick-out and arc length. If the arc voltage is too high and/or the stick-out length too short then penetration will be reduced. Also travel speed has an important influence on penetration and must be fast enough to secure good penetration and to avoid slag running ahead of the weld pool (1G&2G) and weld metal sagging (2G).

Slag inclusions

Possible causes	Remedies
• welding current too low	- increase welding current
• arc voltage too high	- reduce arc voltage
• travel speed too low	- increase travel speed; avoid slag running ahead of weld pool
• pushing technique	- use pulling technique
• torch angle too small	- use 70-90° torch angle; keep slag behind arc
• convex beads	- increase arc voltage or apply some weaving

Centreline cracking on ceramic backing

When welding root runs on ceramic backing strips, centreline cracking (hot cracks) may occur in 1G/PA position. If the current and voltage are too high, a concave bead shape may be formed which, combined with high shrinkage forces, can result in centerline cracking. To avoid centreline cracking, the following guidelines must be observed:



Centreline crack. See page 14 for a correct root run welded on ceramic backing.

- Apply a joint angle of 50-60° and 4-5mm root opening.
- Use ceramic backing with a rectangular groove. The groove width must be around 15mm.
- Use welding currents below 200A (Ø1.2mm) and a not too high arc voltage in order to obtain a flat or slightly convex bead profile.

World leader in welding and cutting technology and systems.

ESAB operates at the forefront of welding and cutting technology. Over one hundred years of continuous improvement in products and processes enables us to meet the challenges of technological advance in every sector in which ESAB operates.

Quality and environment standards

Quality, the environment and safety are three key areas of focus. ESAB is one of few international companies to have achieved the ISO 14001 and OHSAS 18001 standards in Environmental, Health & Safety Management Systems across all our global manufacturing facilities.

At ESAB, quality is an ongoing process that is at the heart of all our production processes and facilities worldwide.

Multinational manufacturing, local representation and an international network of independent distributors brings the benefits of ESAB quality and unrivalled expertise in materials and processes within reach of all our customers, wherever they are located.

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